Thermal and mechanic analyses of nonvolatile and non rotation phase change memory cell

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Abstract

Chalcogenide Random Access Memory (CRAM), also known as Ovonic Unified Memory (OUM) is based on electric induced thermal phase transformation between the amorphous and crystalline states in a chalcogenide phase change thin film. Therefore, the thermal and mechanical performances such as temperature distribution and thermal expansion versus cell structure and electric pulse are very important issues for the CRAM cell design. In this paper, thermal and mechanical analyses are performed on CRAM cells using finite-element method (FEM). In this simulation, two structures shown in Fig. 1 were investigated, where GeSbTe was used as the phase change material, ZnS-SiO_2 as isolation material and TiW as electrode material. Temperature distribution generated by the incident electric pulse was simulated and then the thermal expansion was calculated based on the temperature change.

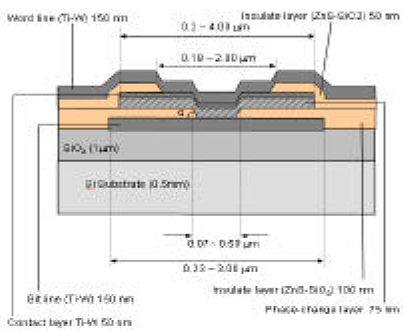

Fig.1 (a) Structure of the simulated CRAM cell.

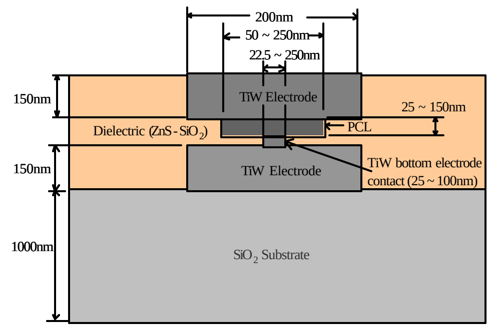

Fig.1 (b) Electric current density in the CRAM cell.

Current flow in the memory cells was calculated and illustrated. The generated heat was evaluated based on it. Thermal and mechanics performances of the cell as a result of power and geometry variations were quantified. Temperature profiles, temperature change, thermal expansion and heat flow characteristics were obtained and analyzed. The parameters of the device, such as layer thickness and cell dimension were varied so as to compare the performance and optimize the structure. Fig. 2(a) and (b) illustrate temperature distribution of the two cells. The results of the heat diffusing to the neighbor cells provide us the information that how small we can integrate the memory array. The heat diffuses not only to neighbor cell but also to the bottom side, which will affect the performance of CMOS. The simulation results suggest us how we can control the heat diffusing towards to the bottom. Fig. 3 shows the thermal deformation distributions in the cells 1(a) and 1(b). The deformation of the structure 1(a) is much larger than that of the structure 1(b).

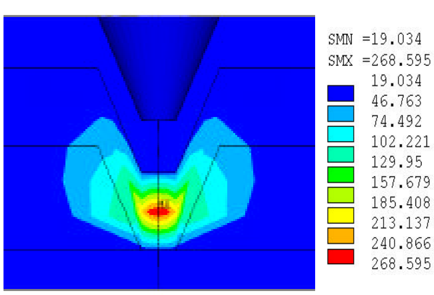

Fig.2 Temperature distribution in CRAM 1(a).

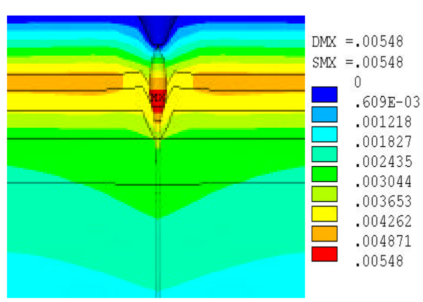

Fig.3 (a) Deformation in CRAM 1(a).

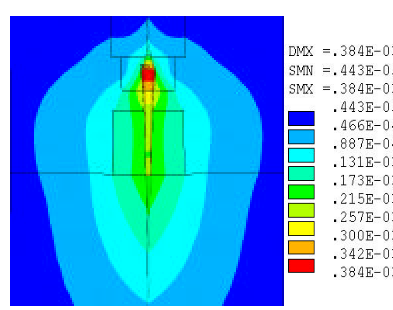

Fig.3 (b) Deformation in CRAM 1(b).

The simulation results show that if the thermal conductivity of phase change layer is reduced the heat diffusion will decrease and the performance of the memory cell may get better. With the guidance of simulation results, we have developed a new structure CRAM cell. The device demonstrated both set and reset pulse width as short as 6ns with twenty times resistance difference. This indicates the device has a high switching/data recording speed.